Integration of Marine Mammal Movement and Behavior into the Effects of Sound on the Marine Environment

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LONG-TERM GOALS

Integration of the Marine Mammal Movement and Behavior (3MB) model into the Effects of Sound on the Marine Environment (ESME) program contributes to the ultimate goal of creating an environmental assessment tool for activities that introduce high levels of sound into the ocean, particularly activities of the U.S. Navy.

OBJECTIVES

The objectives of the effort are to 1) integrate the 3MB module into the second generation model of ESME, 2) incorporate the influence of bathymetric features on simulated marine mammal (animat) movement, 3) develop more species models so that a library of species behavior is readily available for use, and 4) develop a standardized reporting method for the model that provides relevant information to users in the environmental community.

APPROACH

The proposed effort consists of four tasks, some of which will be completed in collaboration with Heat, Light and Sound Inc. (HLS Inc.) and Boston University (BU). Task I involves integrating the current 3MB module with acoustic propagation models by development of application programming interfaces (API). Individual modules will likely consist of MS-DLLs and the initial targeted platform will be Windows-based PCs. Boston University will lead the API development and coordinate efforts on developing efficient data exchange between acoustic and mammal simulation modules.

Task II consists of implementing the ability for animats to interact with the simulated environment, thus more closely approximating biologically relevant behaviors of the simulated species. The candidate model will consist of combinatorial vector operations that determine the relative attraction of environmental features. For the course of the simulation, environmental factors will be assumed to be static.

Task III consists of developing several marine mammal species definitions as a library to be delivered with the ESME model. The species definitions will provide the end-user with a number of pre-defined species with which simulations may be run as well as reference models from which end-users may learn to create their own species definitions. Species model development will be dependent on the availability of dive and movement behavior of marine mammals.

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Task IV involves development of a standard reporting format for results of acoustic exposure simulations. The reports will provide information to individuals involved in estimating impacts of anthropogenic acoustic activities as dictated by NEPA, the MMPA and the ESA. Specifically, take categories (as defined in the MMPA) will be used to categorically assign marine mammals to a level of impact (i.e. Level A (injury) or Level B (behavioral)). The collective information will be useful in post-hoc analysis of the simulated event.

WORK COMPLETED

The 3MB program (v3.0) has been implemented into the ESME integrated model as a series of library calls (Task I). All of the capabilities of 3MB (v3.0) are available to the ESME model except the output of the acoustic impact file, which is determined at the end of a simulation (see below). The current version of 3MB is v4.0. This version contains several ehancements that have not yet been incorporated into the ESME model. These include: 1) an enhancement of the interaction of animats with bathymetric features by permitting boundaries on animat distribution during the initial seeding of the simulation environment, 2) restrictions on animat movement based on sea floor depth (Task II), 3) the seeding of animats within a scenario by input density information, 4) the seeding of animats within a user-defined polygon, and 5) animat replacement within a scenario to keep animat density constant (i.e. animats leaving the scenario region are replaced by new animats at the edge of the scenario region).

An ability to calculate impacts to marine mammals resulting from an acoustic exposure using currently adopted Navy practices was incoporated into 3MB (Task III). Impacts are calculated according impact thresholds and criteria associated with the Level A and Level B harassment definitions of the Marine Mammal Protection Act: specifically, the Level A harassment theshold is an energy metric based on terrestrial mammal studies of permanent threshold shift (auditory injury) which are applied to auditory fatigue measurements made in marine mammals; the Level B harassment has a dual criterion – a energy metric based on measures of temporary threshold shift in marine mammals (e.g. Finneran *et al.*, 2005; Kastak *et al.*, 2005) and a dose-response function that relates the probability of harassment to the maximum sound pressure level of the signals received throughout the simulation. The threshold numbers used to quantify impact are assigned according to species groups arranged by their expected frequency-specific sensitivities: high-frequency cetacean, mid-frequency cetacean, low frequency-cetacean, otariid and phocid (Southall et al., 2007). Impacts are calculated at the end of a scenario and written to an output file of harassment statistics. The 3MB program was given a simplied acoustic exposure scenario capability which can be used to quickly test the acoustic response of modeled species and the harassment calculations. The process allows one animat to act as an acoustic source with source levels of up to 225 dB. The signals are assumed as 1 second tonal sounds and transmission loss is calculated according to spherical spreading.

A new species builder (v3.0) was created to enhance the flexibility in creating species definitions. Origin of species dive behavior is defined with the species builder and species files can be saved for multiple use and updated as new information on species diving becomes available. During the fiscal year species definitions were created for the blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), Cuvier's beaked whale (*Ziphius cavirostris*), Blainsville beaked whale (*Mesoplodon densirostris*) and the harbor porpoise (*Phocoena phocoena*).

RESULTS

The changes made to 3MB over the past fiscal year have enabled flexibility in emulating marine mammal behavior that has not previously been realized. However, the running of simulations with progressively larger animal densities and for longer durations demonstrated that the Monte Carlo nature of 3MB was computationally expensive and resulted in prohibitively long run-times when using thousands of animats and durations of many hours (current limits are 25,000 animats and 72 hour scenarios). As a result of this realization, considerable effort was placed into memory management and file-write methodologies. Dynamic memory management and file-writing methods are now implemented to make optimal use of platform-dependent memory availability. The optimization was essential to ensuring that the use of animats could be maintained as a feasible approach to impact assessment. It has also become apparent that there is a desire to have 3MB capabilities for the emerging availability of 64-bit platforms. To this end, 3MB is currently being modified for use on 64-bit platforms in order to make effective use of emerging computing capabilities.

IMPACT/APPLICATIONS

The integration of the ESME program with the capability to emulate the dive and movement behavior of marine mammals provides a significant advantage to modeling environmental impact than do past approaches used in Navy environmental assessments (EA) and impact statements (EIS). Many previous methods have been statistical or pseudo-statistical approaches that estimate impact by reduction of animal distributions in time and space. Although such approaches may be suitable for range independent environments, they do not approximate the real world and may miss important features of animal behavior and may over- or underestimate impact. Marine mammals make use of environmental characteristics to govern both their dive behavior and distribution within the environment. By implementing animat dive behavior and movement, and having each animat respond to the environment and emulate behaviors according to the species they model, a more realistic assessment of impact can be obtained. Such assessments will have benefit to both the management of animal stocks and in providing relief from legal issues grounded on the misinterpretation of prior modeling assumptions and outcomes.

TRANSITIONS

The 3MB program has been adopted by the Naval Undersea Warfare Center (NUWC) as their animat control program for their acoustic impact analyses. The NUWC is responsible for modeling marine mammal acoustic impacts for a number of environmental impact statements (EIS) related to major Navy actions and Navy ranges (e.g. Undersea Shallow Water Training Range EIS, Atlantic Fleet Active Sonar Training EIS/OEIS). Adoption of the 3MB and the process of integrating it into the NUWC impact models began in June 2008. No acquisition funds have been committed to this process.

REFERENCES

Finneran, J. J., Carder, D. A., Schlundt, C. E., and Ridgway, S. H. (2005). "Temporary threshold shift (TTS) in bottlenose dolphins (Tursiops truncatus) exposed to mid-frequency tones," Journal of the Acoustical Society of America 118, 2696-2705.

Kastak, D., Southall, B. L., Schusterman, R. J., and Kastak, C. R. (2005). "Underwater temporary threshold shift in pinnipeds: effects of noise level and duration," Journal of the Acoustical Society of America 118, 3154-3163.

Southall, B. L.; Bowles, A. E.; Ellison, W. T.; Finneran, J. J.; Gentry, R. L.; Greene, C. R.; Kastak, D.; Ketten, D. R.; Miller, J. H.; Nachtigall, P. E.; Richardson, W. J.; Thomas, J. A.; Tyack, P. L. (2008). "Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations," Aquatic Mammals 33, 411-521.

PUBLICATIONS

Houser, D. S. 2006. A method for modeling marine mammal movement and behavior for environmental impact assessment. IEEE Journal of Oceanic Engineering. 31(1):76-81. [published, refereed]